**Final Report: Cloud Ozone Dust Imager (CODI)**

Planetary Instrument Definition and Development Program
Contract NAG5-3714

Principal Investigator: R. Todd Clancy
Space Science Institute
Boulder, CO
Co-Investigators: George Lawrence, Bill McClintock
Laboratory for Atmospheric and Space Physics
University of Colorado, Boulder
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**Instrument Description**

The Cloud Ozone Dust Imager (CODI) project has developed an imaging system which provides combined capabilities for wide field of view climate monitoring and landing site surveys on Mars. CODI is designed to measure (1) opacities, waveforms, dust particle properties (size, shape, and alignment), and heights of clouds; (2) the opacities, particle properties, and vertical distribution of dust; (3) the opacity and vertical distribution of ozone.

The CODI wide angle (WA) camera employs shuttered, hemispheric (140°) field of view optics, separate filter and polarization wheels, and a back-illuminated Scientific Imaging Technology (SITE) 1024 x 1024 CCD array. The lens shutter includes open positions for direct solar viewing (small aperture, for dust cloud extinction measurements) and non-solar viewing (large aperture for sky/surface imaging). The CODI optical system consists of 4 UV-transmissive $CaF_2$ optical elements (two catalog stock and two custom lenses). At the edges of the field of view, the resolution is limited by lateral chromatic aberration to 2 pixels, except for the 953 nm channel where the CCD resolution (for 24 micron pixels) is 4 pixels. The lens is telecentric, that is, the output rays of the lens are nominally parallel to the optical axis (infinite image of the entrance pupil) and thus maintain the same filter function over the image.

Simultaneous sky/surface imaging of Mars can be obtained at an angular resolution of 0.28° for wavelengths of 255, 336, 502, and 953 nm. These wavelengths measure atmospheric ozone (255 and 336 nm), discriminate ice and dust aerosols (336 and 953 nm), and provide color images (336, 502, and 953 nm). The filters are alumnium-$MgF_2$ layers on quartz substrates (Barr Associates). These are reproductions of HST WFPC filters, with special attention paid to out-of-band blocking for the UV bands. Imaging is obtained with separate, overlapping filter and polarizer wheels. Standard imaging is through a clear position on the polarizer wheel, but all four filter positions can be viewed through any of three Stirling UV polarizers (linear polarization orientations, rotated at 0, 60°, and 120°) on the polarizer wheel. These linear polarization measurements are a powerful probe of atmospheric aerosol properties. The polarimetric phase function is particularly sensitive to the shape and orientation (i.e., particle alignment) of scattering particles. The complete polarimetry, wavelength and full angular observations of dust/cloud scattering allow sensitive determinations of suspended aerosol properties.

In anticipated Mars surface applications, an actuated cover protects the lens from dust accumulation and, when partially opened, can redirect the WA field of view for more complete surface viewing in support of surface science, lander/rover operations, and/or descent imagery. (The actuated cover was developed as a design concept but not incorporated into the breadboard prototype). A 20° to 40° (or greater) surface field of view would extend seamlessly through the horizon to overhead. CODI can then provide surface polarization measurements which can indicate correlations with surface texture and porosity. CODI can also measure UV surface reflectances of the landing site and provide a sensitive means of detecting surface ice. Data masking algorithms can be used so that only specific portions of CODI images need be routinely transmitted back to Earth.

**Table 1. Summary of CODI Instrument Characteristics**

| | |
|---|---|
| Mass | 850 grams + electronics box (350 grams) |
| Volume | 125 mm wide x 113 mm long x 65 mm tall |
| Daily Average Power | 0.09 Watts |
| Daily Energy Consumption | 0.08 Amp Hours @ 28 V |
| Field of View | 140° total, 0.14°/pixel |
| Focal length | 4.9 mm |
| Filter wavelengths (nm) | 255, 336, 501, 953 |
| Filter FWHM bandwidths (nm) | 25, 25, 5, 5 |
| Stirling UV polarizers | 0°, 60°, 120° |
| Optics | 4 element CaF2, telecentric, f/12.5 |
| Shutter: mechanical at entrance pupil | On, off, sunglasses |
| Mechanisms | 3 stepper motors, filter, polarizer, shutter |
| Imager Type | SITE back-illuminated, AR-coated CCD |
| Imager Format | $(1024)^2$ ; 24 micron pixels; full-frame |

Important mechanisms in CODI include:

Filter and polarizer wheels

The filter wheel is a 76.2 mm pitch diameter aluminum gear (with teeth hardened by NiTuff). Four filters are mounted in holes cut in the face of the gear. It is rotated by an acetyl pinion on a stepper motor at the edge of the gear. We have run these prototype filter wheels to 250,000 revolutions with no failures and no microscopic evidence of wear. Optical shims on each filter provide focus at each wavelength. The polarizer wheel is mechanically the same as the filter wheel except for a slight increase in the filter hole size. This wheel contains 3 Stirling Optics type fused silica UV105 polarizers, mounted at 0°, 60°, 120°. The fourth position is unpolarized but contains a window to equalize the optical path length.

Shutter and iris

The shutter (at the entrance pupil) is a lightweight blade with two apertures mounted directly on a stepper motor shaft. It has 3 positions (limited by stops) and an operation time of 2 msec. The shutter controls the exposure time and also has a reduced aperture position to enable exposures with the sun high in the sky. The sun images measure atmospheric transmission and small angle scattering of the atmospheric dust.

Stepper motors

The polarizer, filter, and shutter stepper motors are all ASAPE (Donovan) AM1524 Swiss motors which provide at least two orders of magnitude torque margin and operate with dry lubrication at liquid helium temperatures (proven at 77 K, 4 K, and room temperature). The three dry lube materials we have considered are: Teflon impregnated anodizing (NiTuff), molybdenum disulfide, and tungsten disulfide (Ultralube). The 3 motors are cyclical (full revolution devices). The shutter motor uses only the motor bearing.

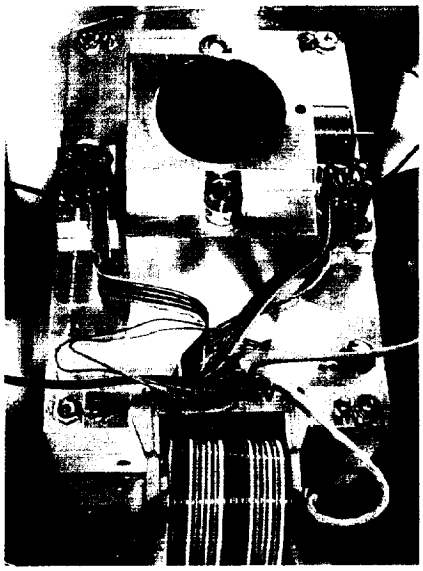

**Figure 1:** CODI breadboard in thermal test chamber

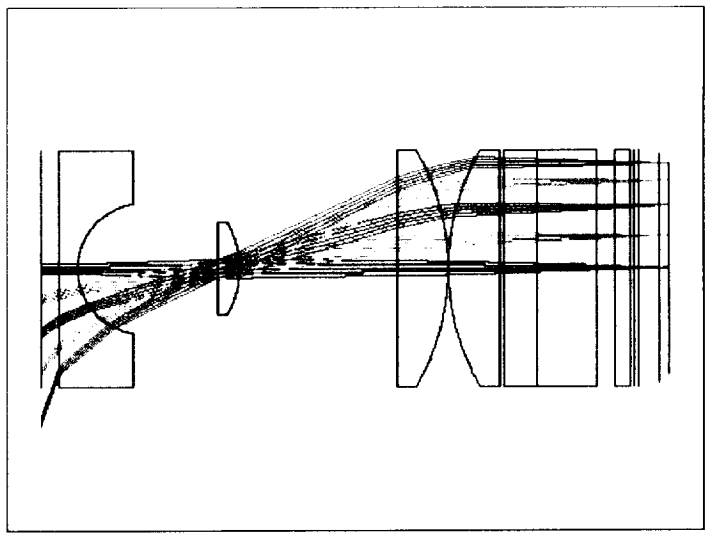

**Figure 2:** CODI Raytrace (Zemax)

**Overview of Program Accomplishments**

We completed development of the CODI breadboard prototype (Figures 1, 2 and attached grid target image). This included the following activities:

- Design and development of optical assemblies that maintain focus over the entire CODI operating temperature.
- Development of athermalized designs for reliable mechanisms including stepper motors and other actuation equipment for polarizer and filter wheels to function over -130° C to + 50° C temperature range.
- Developed instrument ruggedization, athermalization, and dust proofing strategies now being adapted for use in other Mars surface prototype instruments.
- Submittal of two highly rated proposals for flight: CODI for the Mars Surveyor 98 lander and the multi-instrument suite DIME (Dust Imaging Experiment) for the Mars Surveyor 2001 lander (see the enclosed documents). These proposals included realistic integration strategies and operational scenarios for Mars Surveyor landers. CODI will also be proposed as part of a two-instrument suite for the 2003 Mars Surveyor lander.

# Result Image:Result Image:grid617b

Image Height: 1200 Image Width: 1099 Image Bpp: 16

Full Image Stats:

| | |
|---|---|
| Mean: | 24597.32 |
| Variance: | 128273367.34 |
| StdDev: | 11325.78 |
| Min: | 0 |
| Max: | 59970 |